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PARTICLE DETECTION***

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STUDY OF MWPCS WITH INTERPOLATING PAD READOUT FOR HIGH MULTIPLICITY CHARGED PARTICLE DETECTION*

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Abstract

Two types of MWPC with interpolating cathode "pad" readout for two dimensional position sensitive detection have been studied. One type uses rectangular pads and resistive charge division. A detector with an active area of 26cm \times 16cm, over 1000 readout channels has been built. With readout spacing of 1cm, a position resolution of $\sim 70\mu\text{m}$ (rms) for 5.4 keV X-rays and a differential non-linearity of $\pm 6\%$ have been achieved. Another type of detector uses "chevron" shaped pads for geometrical charge division. Position resolution $\sim 50\mu\text{m}$ (rms) for 5.4 keV X-rays has been observed in a test detector and results of an investigation to reduce differential non-linearity are reported.

Introduction

Two types of position sensitive detector have been studied at BNL. The "Pad Chamber" [1-2] is a detector with a cathode plane divided into a large number of rectangular pads (see Fig. 1). Anode wires are placed above the pads, and field wires with ground potential are placed between anode wires. All pads beneath one anode wire are interconnected by a resistive strip. Approximately every tenth pad is read out by a charge sensitive preamplifier. An avalanche created by a charged particle traversing the detector induces localized charge on several pads. The position of the avalanche can then be found by calculating the centroid of the charge collected from these pads [3]. Unambiguous pattern recognition is achieved because of this two dimensional segmented cathode layout.

The "Chevron Pad Detector", in which the rectangular pads and the resistive layers are replaced by rows of chevron shaped pads as the cathode (shown in Fig. 2), has also been studied. Each pad is read out by a charge sensitive preamplifier. In this scheme, position sensing is achieved by geometrical charge division [4-5].

Pad Chamber with Resistive Charge Division

The design and construction of two versions of this detector are reported in Refs. [2] and [6]. The prototype detector [2] has an active area of 20cm \times 10cm, with 525 readout channels. Monte Carlo studies have shown that this detector, with 1000 electrons rms noise and a gas gain of 10^4 , can resolve a minimum ionizing particle track multiplicity of 20 with an efficiency of 96% [1]. The full-sized detector [6] has an active area of 26cm \times 16cm,

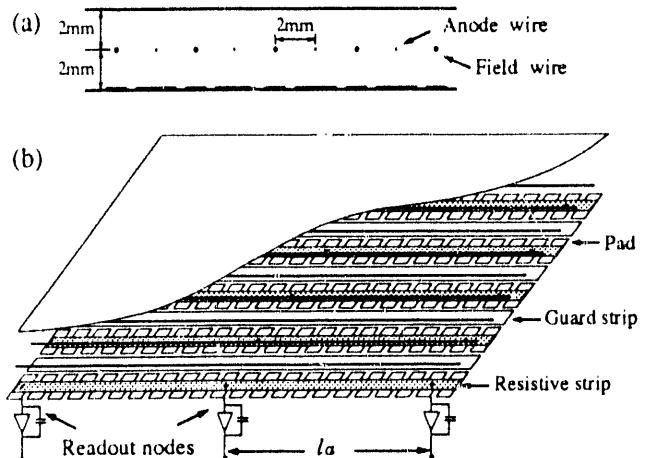


Figure 1: Schematic of a Pad Chamber. (a) Cell geometry viewed along the wire direction. (b) "3-D" view of the Pad Chamber.

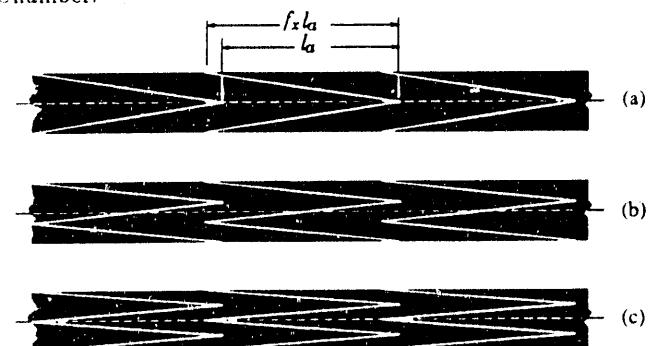


Figure 2: Three types of chevron pad cathode: (a) "Single chevron," (b) "One and a half chevron," (c) "Double chevron." (The dashed lines indicate anode wire positions.)

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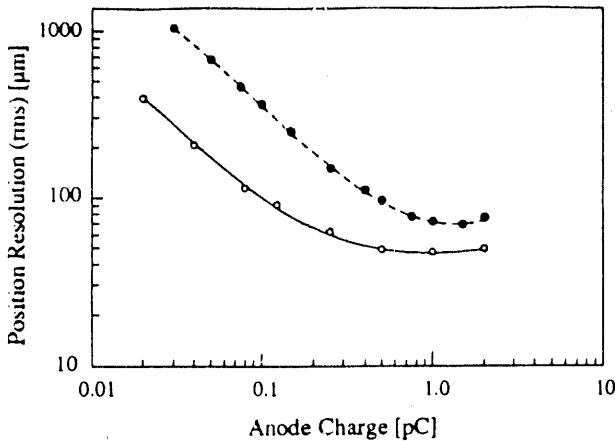


Figure 3: Position resolution as a function of anode charge for a pad chamber (solid circle, $l_a = 10$ mm, anode charge was measured with a 200 nsec time constant, 90% Ar / 10% CH₄ gas mixture), and a chevron pad chamber (hollow circle, $l_a = 12$ mm, single chevron, $f_x = 1.05$, anode charge was measured with a 1 μ sec time constant, 50% Ar / 50% C₂H₆ gas mixture). Radiation was 5.4 keV X-rays.

with 1016 readout channels. Both detectors use fiberglass honeycomb material on their thin cathode printed circuit boards to maintain their flatness and rigidity, which resulted in the cathode boards representing only 0.6% of a radiation length.

Absolute position resolution and linearity of the detectors have been measured by means of an electronic centroid finding system, in which the centroid of charge is determined by convolution of the sequentially switched outputs from several readout nodes with a linear centroid finding filter [7]. The test was performed with a 15 μ m wide collimated X-ray beam and with a gas mixture of 90% Ar / 10% CH₄. The anode charge was measured with a 200 nsec shaping time. Figure 3 shows the behavior of the position resolution versus anode charge Q_A in the prototype chamber with a readout node spacing of 1 cm. For Q_A up to approximately 0.2 pC, the resolution improves according to a $1/Q_A$ relationship, since the electronic noise is the only significant perturbing factor. For Q_A above 0.2 pC, however, the position resolution improves more slowly than $1/Q_A$ because of the influence of phenomena such as electron range and diffusion. A minimum value of about 70 μ m (rms) was attained for $Q_A \sim 1.5$ pC. Higher charge levels cause progressive deterioration in resolution because of spreading of the avalanche along the anode wire.

Differential non-linearity measurements have been made by obtaining a uniform irradiation response (UIR), with 5.4 keV X-rays, from a section of the anode wire. The preamplifier signals were fed to the centroid finding system and the resulting position signals analyzed with a pulse height analyzer. Figure 4a shows the UIR across eight readout nodes of the prototype pad chamber. The

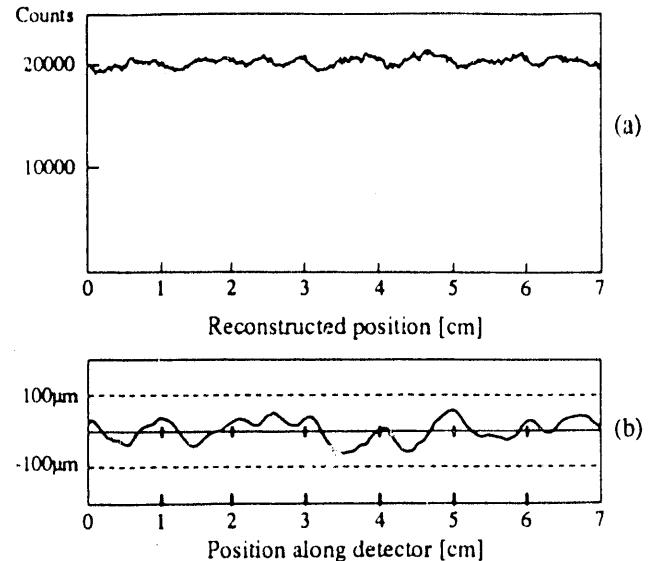


Figure 4: (a) Uniform Irradiation Response of a section of the prototype pad chamber. (b) Reconstructed position error derived from the spectrum in (a).

positions of the readout nodes, separated by 1 cm, correspond to the tick marks on the abscissa. Differential non-linearity is better than $\pm 6\%$. Figure 4b shows the absolute position error ($\pm 60 \mu$ m), which was derived by evaluating integral non-linearity.

Pad Chamber with Geometrical Charge Division

A test chamber with interchangeable chevron cathode planes has been built to study their linearities and position resolutions. Its cell structure is identical to that of the pad chamber with resistive charge division. The testing of the chevron pad chamber was performed with the same centroid finding system as described earlier and 5.4 keV X-rays. The gas mixture used was 50% Ar and 50% C₂H₆. For a "single chevron" cathode (as shown in Fig. 2a) with $l_a = 12$ mm, a position resolution of $\sim 50 \mu$ m has been observed at an anode charge level of 0.5 pC (measured with a 1 μ sec time constant), as shown in Fig. 3. Experimental results indicate that for each type of geometry, the best linearity can be obtained with f_x (see Fig. 2) slightly greater than unity. A similar behavior has also been observed with zigzag strip cathodes [8].

One interesting phenomenon observed is the effect of the anode avalanche angular localization [9] on the position accuracy and linearity of the chamber. If a narrow beam of X-rays is incident on the detector from directly above one of the anode wires, X-rays are absorbed both above and below this wire. The induced charge on the chevron cathode pads for events initiating an avalanche on top of the wire (window side events) is different in time development and charge distribution from that for events from below the wire (pad side events). The sizes of induced charge from pad side events are smaller than that

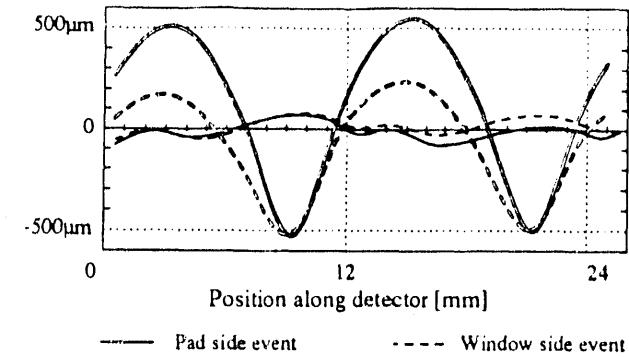


Figure 5: Comparison of reconstructed position errors between a single chevron cathode (shown in hollow lines) and a double chevron cathode (shown in solid lines). $l_a = 12$ mm and $f_x = 1.05$ for both cathodes.

of the window side events. If the width of the chevron is large compared with the size of the induced charge, it will result in poor sampling and, therefore, an error in the reconstructed position. The pad side events suffer more because of their smaller sizes of induced charge. This can result in a considerable difference in the reconstructed centroid position. A special filtering technique [9] allows us to select one type of event over another. The hollow lines in Fig. 5 show the reconstructed position errors from these two types of event obtained from two scans with collimated X-ray beam. The cathode pads are single chevrons, $l_a = 12$ mm, $f_x = 1.05$, and the gap width between chevrons is about $60\text{ }\mu\text{m}$.

In order to minimize this position splitting, several other chevron patterns have been tested. Figure 2 (b) and (c) show two of them. These cathodes demonstrated significant improvements both in the reconstructed position linearity and the window side-pad side splitting. Figure 5 shows the experimental results of a double chevron and a single chevron. Figure 6 shows the measured differential non-linearities of some of the chevron patterns we tested. Details of this study will be reported elsewhere [10].

This splitting of centroid position for X-ray events is more pronounced with a long sampling time constant ($1.4\text{ }\mu\text{sec}$ in our system) and a small anode-cathode spacing. For the case of a finely collimated beam of charged particles, a single position peak will be observed. Fluctuation of ionization clusters along the particle tracks will, however, cause a broadening of the position peak. A shorter time constant or a larger anode-cathode spacing will reduce the splitting and the broadening.

Conclusions

Both types of pad detector have been built and used in the E814 heavy ion experiment at the AGS in BNL [11]. Their ability to handle high particle multiplicity and provide unambiguous two-dimensional position information (1-3% of the readout node spacing along the wire direction) offers a very powerful detector technique. Pad

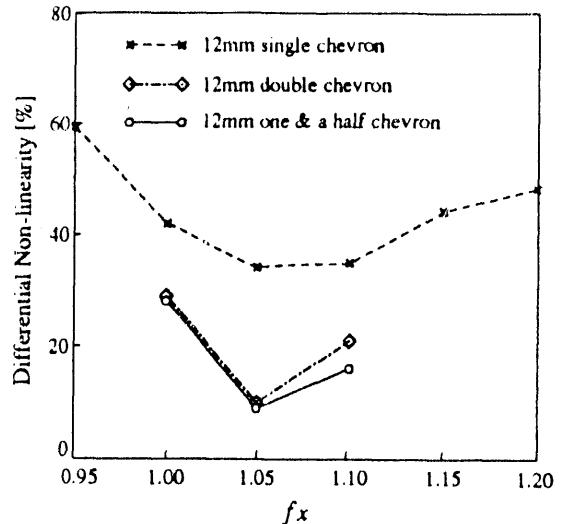


Figure 6: Differential non-linearity versus f_x for several chevron patterns

chambers with resistive charge division can provide very good position resolution and linearity. By using laser or abrasive trimming of resistors, one can expect to reduce the differential non-linearity down to the 2% level. However, resistor trimming on a detector with large active area becomes more difficult. Therefore they are most suited for small detectors or larger detectors whose cathodes can be divided into small modules. On the other hand, chevron pad cathodes which are relatively simple to fabricate, can be made in various sizes. They can provide excellent position resolution and good linearity with optimized chevron geometries. Such interpolating "gas pixel detector" with unambiguous two dimensional readout will be essential at the SSC as special layers in the barrel tracking detector and particularly in forward direction.

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